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WATER QUALITY OF RUNOFF TO THE CLARKSVILLE MEMORIAL HOSPITAL DRAINAGE WELL AND OF MOBLEY SPRING CLARKSVILLE, TENNESSEE, FEBRUARY–MARCH 1988

Prepared in cooperation with the

TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT
DIVISION OF CONSTRUCTION GRANTS AND LOANS

U.S. GEOLOGICAL SURVEY

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By Anne B. Hoos

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Nashville, Tennessee
1988

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CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

For use of readers who prefer to use International System (SI) units, rather than the inch-pound terms used in this report, the following conversion factors any be used:

Multiply	By	To obtain
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter(m)
gallon	.003785	cubic meter (m^3)
gallon per minute (gal/min)	0.0630	liter per second (L/s)
microsiemens per centimeter at 25 °C (uS/cm)	1	micromhos per centimeter at 25 °C (umhos/cm)

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By Anne B. Hoos

ABSTRACT

A drainage-well and a spring site in Clarksville, Tennessee, have been instrumented to collect storm-related data in order to define the types and concentrations of water-quality characteristics in stormwater runoff and in the receiving ground-water basin. Water-quality samples of storm runoff at the drainage well at Clarksville Memorial Hospital and of nearby Mobley Spring were collected during four storms and during normal flow conditions during the period February to March 1988.

Samples were analyzed for major inorganic water-quality constituents, selected trace metals, and organic compounds. Several samples from the drainage well and the spring had trace-metal concentrations that exceeded maximum contaminant levels for State drinking-water standards. Organic compounds including phenols, polynuclear aromatic hydrocarbons, and other base-neutral extractable organic substances are present in samples from both the drainage well and spring.

INTRODUCTION

Stormwater runoff from urban areas has been recognized for the past decade as a source of contamination to receiving surface- and ground-water bodies. Urban runoff can enter the ground-water system either by diffuse infiltration, or, in karst areas, at discrete points through conduits in the bedrock. In the karst areas, the direct entry of runoff through surface features such as sinkholes and sinking streams, and the rapid movement of ground water through the well-developed subsurface drainage network cause slug transport of contaminants through the aquifer, which in turn may create acute and periodic water-quality problems. These problems are compounded by the practice of constructing drainage wells to reduce flooding in areas with no surface drainage. Removal of the unconsolidated material from the mouth of the sinkhole increases the peak contaminant levels in ground water following storm events, and may actually increase the overall load of contaminants to the system.

The U.S. Geological Survey, in cooperation with the Division of Construction Grants and Loans of the Tennessee Department of Health and Environment, has begun an investigation of the impacts to ground-water quality from diverting urban runoff to drainage wells. The rapidly urbanizing area of Clarksville, Tennessee (fig. 1), was selected as the site for this investigation because of its location in a well-developed karst terrane, and because a number of drainage wells are currently in use in this area to reduce the considerable surface-flooding problem.

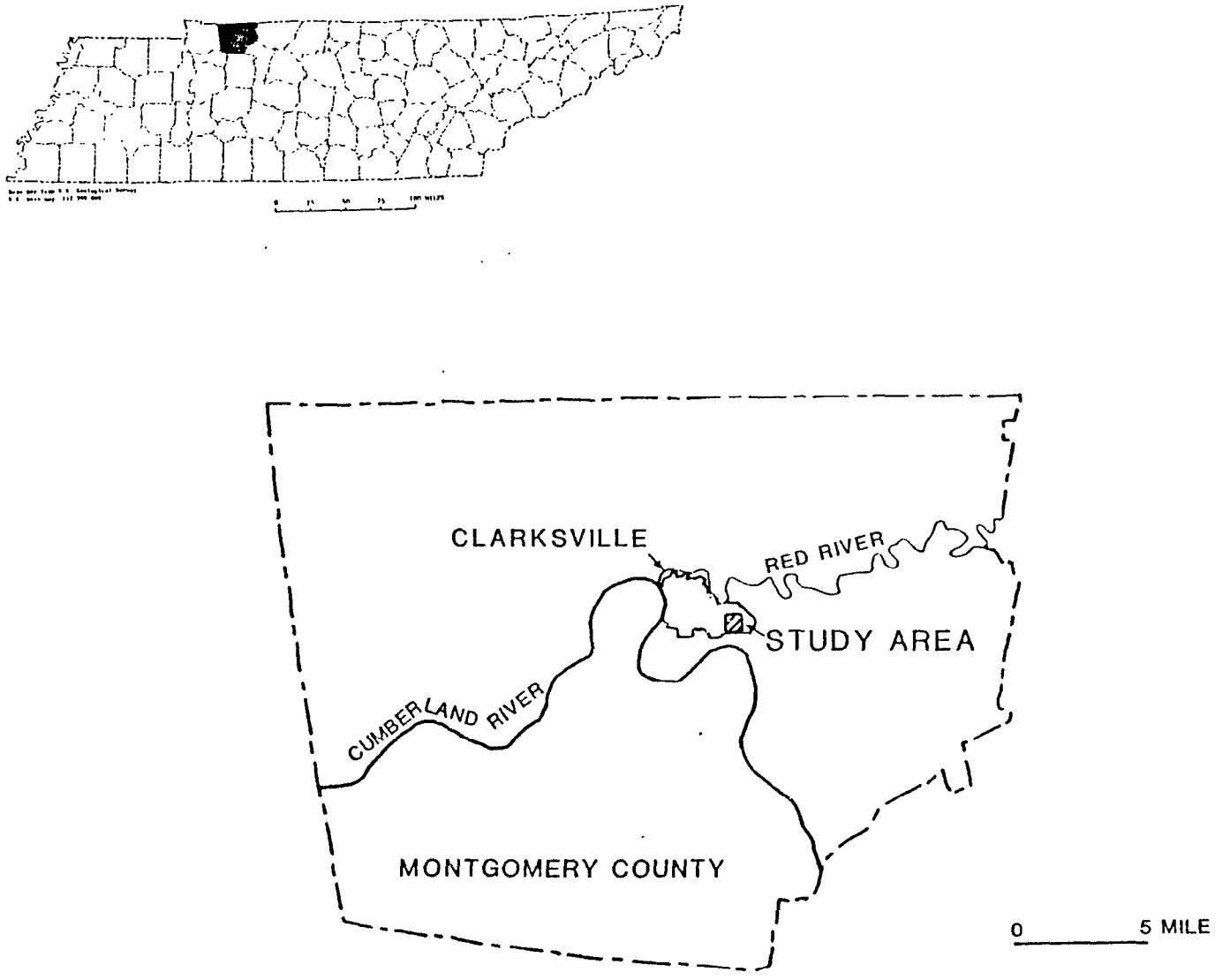

Figure 1.--Location of study area near Clarksville, Tennessee

Purpose and Scope

The purpose of this investigation is to characterize the quality of urban runoff entering a drainage well in Clarksville, Tennessee, and of the receiving ground-water body. This report describes the data-collection program currently in operation for this investigation and reports water-quality constituent concentration data collected during four storm events and normal flow conditions in February and March 1988.

Previous Studies

Milligan and others (1984) examined urban runoff quality and quantity in an area underlain by carbonate rock near Knoxville, Tennessee. Although their results suggest the possibility of aquifer contamination by urban runoff flowing into sinkholes, the ground-water quality data needed to confirm this were not available. The Federal Highway Administration (1981) monitored the quality of highway runoff during a 12-month period from Interstate 40 in Nashville, Tennessee. Crawford and Groves (1984) inventoried stormwater drainage wells in karst areas throughout Kentucky and Tennessee.

Acknowledgments

The author wishes to thank Mr. Charles Mobley, Mr. Jack Uffelman, and the staff of the Clarksville Memorial Hospital for their permission to install hydrologic stations and instrumentation on their property. Dr. Phillip Kemmerly shared his knowledge of the hydrogeology of the Clarksville area. D.S. Mull provided guidance and assistance in the dye-trace investigation.

COLLECTION OF HYDROLOGIC DATA

Data-Collection Program

Site Selection and Description

The following criteria were used in the selection of the monitoring site:

(1) The drainage well drains a high density commercial or residential area.

(2) Watershed boundaries for the drainage well are well defined, so that all influences to the quality of runoff can be identified. An area in which point sources of contamination are known to contribute to the runoff is deemed unsuitable.

(3) Priority was given to sites with existing wells and springs along the proven path of ground-water flow from the drainage well, providing sampling points of the receiving ground-water body. Springs estimated to drain large (greater than 10 square miles) ground-water basins were considered unsuitable sampling points because of the probable dilution of constituents introduced and measured at the drainage well by unaffected ground water.

(4) Travel time of ground-water flow between the drainage well and ground-water sampling points should be of sufficient length to permit observation of any physical or chemical reactions modifying concentrations of constituents. However, distance between the drainage-well and ground-water sampling points should not be so great as to allow a significant volume of recharge to enter the aquifer along the flow path and dilute the system.

The selected drainage-well site and its watershed boundary are shown in figures 2 and 3. The watershed boundary was delineated by the Soil Conservation Service (1986). The 12-acre watershed consists of approximately 90 percent paved parking lots and rooftops of the Clarksville Memorial Hospital complex, with the remaining area residential (fig. 3). Two drainage wells (fig. 3), approximately 5 feet apart, have been installed at the bottom of a depression and are the only outlet for runoff from the drainage area. The wells are estimated to be 10 and 30 feet in depth, with corrugated steel casing and raised metal grates.

Karst topography is well developed in the study area, with numerous topographic depressions, or sinkholes, resulting from settlement of surface materials into solution openings beneath the surface (Kemmerly, 1980). Sinkhole density is estimated to range between 5 and 40 per square miles (Kemmerly, 1980). The residual soil is a clay matrix with nodules of dense chert, ranging in thickness from 0 to 30 feet. The bedrock (Mississippian age St. Louis and underlying Warsaw Limestones) is deeply weathered, with numerous openings developed by solution along bedding planes. The contact between the St. Louis and Warsaw Limestones is exposed in some of the draws adjacent to the Red River (fig. 1), and is the origin of several springs in the area.

Dye-trace Investigation

Flow direction from the drainage well was determined using a fluorescein dye-trace test. Approximately 0.8 pound of fluorescein dye (Acid Yellow 73) was mixed with 5 gallons of water and poured into the deep (30 feet) drainage well at 12:50 PM, January 21, 1988. The sink was dosed with approximately 20,000 gallons of water (released from a nearby fire hydrant at a flow rate of 480 gal/min) just prior to injection, in order to wet the subsurface conduit surfaces (Mull, Liebermann, Smoot, and Woosley, written commun., 1988). Three springs (fig. 2) judged to be possible resurgent points for ground water flowing below the drainage-well site were monitored for a 7-day period for the presence of dye. Two of the springs (Mobley Spring and Chip'n'Dale Road Spring) issue from the contact between the St. Louis and Warsaw Limestones. Dye-monitoring apparatus consisted of a nylon mesh bag containing activated coconut charcoal suspended in the flow below each resurgence.

Dye recovery below Mobley Spring was verified by elutriating the exposed charcoal in a basic alcohol solution (Mull, Liebermann, Smoot, and Woosley, written commun., 1988). Because the dye cloud passed this site during the night following the injection (between 7:30 PM January 21 and 7:20 AM January 22), the time of travel between the drainage-well site and Mobley Spring is estimated to range from 6.7 to 18.5 hours. Dye was not detected at the other monitoring sites (Gary Court and Chip'n'Dale Road) during the 7-day period following injection.

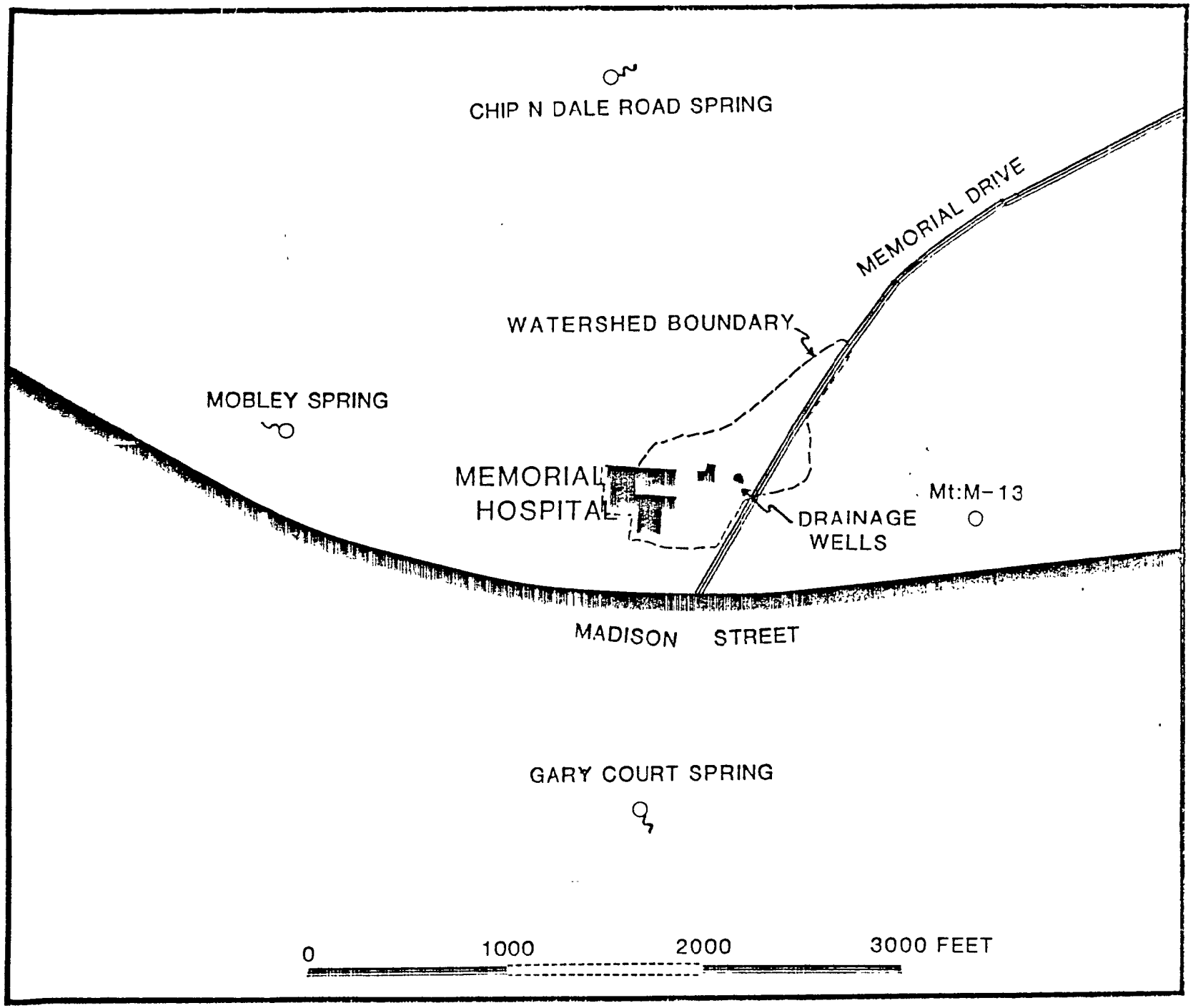

Figure 2.--Location of drainage well with associated watershed boundary, springs, and well Mt:M-13.

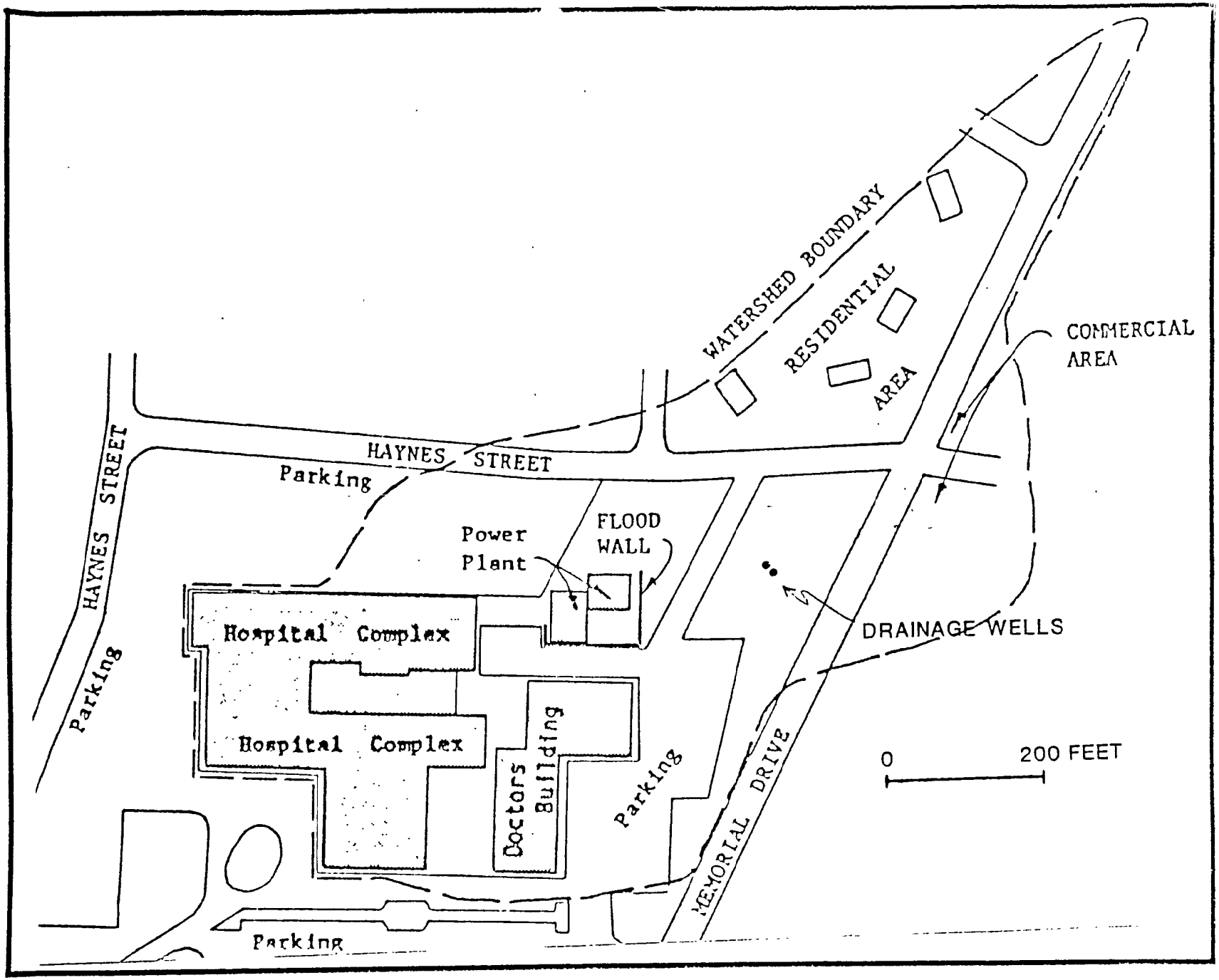

Figure 2.--Location of drainage well and land-use features in the watershed.

Following verification of the direct connection between surface drainage at the drainage-well site with the ground-water system flowing to Mobley Spring, the two sites were instrumented to collect storm-related data in order to define the water quality of stormwater runoff and in the receiving ground-water basin. Sampling equipment and stage gages were installed at both sites in February 1988. Water samples from storm events and from normal flow conditions were collected during February and March.

Water samples will be collected during April and May 1988 from water-table wells along the ground-water flow line intersecting the drainage-well site and spring, both upgradient and downgradient from the site. The upgradient water sample will be obtained from an existing well (Mt:M-13) located approximately 1,200 feet east of the drainage-well site (fig. 2) and will provide information on the quality of ground water unaffected by the runoff entering the drainage well. Drilling has been planned for late April in order to provide a downgradient ground-water sampling point between the drainage-well site and the spring.

Methods of Data Collection

Sampling Equipment

Sample collection was automated to permit collection of samples at the beginning of a runoff event, before monitoring personnel could reach the site. Water-quality samplers (ISCO Models 1680 and 2100) were installed at the drainage-well site and spring to collect discrete samples at intervals of 5 and 10 minutes, respectively. Each sampler was wired to a stage recorder through a contact closure that was activated when a preset liquid level was reached.

Precipitation Measurement

Precipitation data were obtained from a tipping-bucket rain gage operated by the U.S. Army Corps of Engineers on the Red River near Clarksville. The gage is located approximately 3.5 miles northwest of the study site.

Stage Measurement

Stage at the drainage-well site (gaging station Hospital Sink Hole at Clarksville, Tennessee, 03436138) is measured with a Stacom manometer and recorded on a digital recorder at 5-minute intervals. A stage-volume relation was estimated from elevation data provided by the Soil Conservation Service (Larry Hasty, Soil Conservation Service, written commun., 1988). A relation between stage in the sinkhole basin and discharge through the sink outlet (drainage wells) was developed by pairing each stage value on the receding limb of the stage hydrograph with the corresponding incremental volume change calculated from the stage-volume relation.

Stage in the channel immediately downstream of the spring outlet (gaging station Mobley Spring at Clarksville, Tennessee, 03436139) was measured with a

stilling well and recorded on a digital recorder at 5-minute intervals. Discharge from the spring was estimated from stage data through a stage-discharge rating developed for the channel.

Sample Collection

The schedule of sampling during a storm varied for each of the four storm events (table 1). Samples from storm 1, February 5, 1988, which predated installation of the automated sampling equipment, were collected as a single grab sample at each site. The objective of operating the automated sampling equipment is to collect samples before, during, and after the storm hydrograph peak at both sites. The sample sets from storms 2 and 3 are not complete, however, because of initial difficulty in establishing proper settings of equipment controls. At least one sample from each event was analyzed for major constituents, total organic carbon, selected trace metals, oil and grease, and presence of organic compounds.

A water sample from Mobley Spring was collected during normal flow conditions on February 29, 1988, to obtain information on background levels of constituents in ground water.

Sample Handling and Analysis

Samples were retrieved from the automatic samplers and placed in insulated containers as soon as monitoring personnel could reach the site following the storm, then transported to the Nashville field office. Measurements of specific conductance were performed either at the sampling site or shortly after transport to the field office. Samples were composited when necessary to achieve sufficient volume for analyses. The samples were packed with ice and sent to the U.S. Geological Survey laboratories in Arvada, Colorado and Ocala, Florida for analysis.

Analytical methods for the determination of major constituents and selected trace metals are described in Fishman and Friedman (1985). Analytical methods for total organic carbon and oil and grease determination, and for screening for the presence of organic compounds by gas chromatography and flame ionization detection (GC/FID) are described in Wershew and others, 1987). The GC/FID analysis provides semi-quantitative data on the presence and levels of organic substances. Although individual compounds cannot be identified, retention times on the GC column and concentrations [with variable minimum detection limits ranging from 1 to 50 micrograms per liter (ug/L)] for each compound are determined, providing a 'fingerprint' of the organic substances in the water sample. Seven groups of organic compounds, the methylene chloride-extractable compounds (listed in the Appendix), may be detected by this method.

Results of Water-Quality Analyses

Results of analyses of samples collected from the drainage-well site and spring during three storms and from the spring during normal flow conditions are given in tables 2 and 3. Trace-metal analyses of samples from the spring

Table 1.--Summary of hydrologic conditions and sampling schedule at test sites for each sampling event

[S = standard analysis (major constituents, specific conductance, total organic carbon) (see table 2); T = selected trace-metal analysis (see table 3); O = oil and grease analysis (see table 3); G = gas chromatograph flame ionization screening of organic compounds (see figures 4-7); NR = no record]

Site	Storm	Date	Rainfall (in)	level rise (ft)	Sample type	Analyses
			[1]			
Mobley Spring	--	02/29/88	0.00	0.00	Single	S,T,O,G
Drainage well	1	02/02/88	1.47	NR	Single	S,T,O,G
Mobley Spring	1			NR	Single	S,T,O,G
					[2]	
Drainage well	2	02/14/88	1.04	NR	Time-composite - 1 sample	T,G
Mobley Spring	2			0.53	Time-composite - 1 sample	T,G
					[2]	
Drainage well	3	02/19/88	0.28	NR	Time-composite - 1 sample	S
Mobley Spring	3			0.06	None	
Drainage well	4	03/25/88	0.15	0.27	Time series - 28 samples	S,T,O,G
Mobley Spring	4			0.04	Time series - 28 samples	S,T,O,G

[1] Samples were taken during normal flow conditions

[2] Insufficient volume in each sample bottle required compositing to a single sample.

Table 2.--Temperature, specific conductance, pH, total organic carbon, potassium, major anion, and alkalinity data for samples from storms 1-4 and from normal flow conditions

STORM	DATE	TIME	TEMPERATURE WATER (DEG C) (00010)	SPECIFIC CONDUCTANCE (US/CM) (00095)	PH LAB (STANDARD UNITS) (00403)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	POTASSIUM, DISSOLVED (MG/L AS K) (00935)	CHLORIDE, DISSOLVED (MG/L AS CL) (00940)	SULFATE DISSOLVED (MG/L AS SO4) (00945)	FLUORIDE, DISSOLVED (MG/L AS F) (00950)	ALKALINITY LAB (MG/L AS CACO3) (90410)
			03436138	- HOSPITAL SINKHOLE AT CLARKSVILLE, TN							
	FEB										
1	02...	1630	8.0	65	7.10	2.8	0.60	3.8	5.4	0.20	22
	FEB										
2	14-14	1515	--	650	--	--	--	--	--	--	--
	FEB										
3	19-19	0700	7.5	122	7.50	--	--	--	--	--	--
	MAR										
4	25...	0700	20.0	155	--	--	--	--	--	--	--
	25...	0710	20.0	115	--	--	--	--	--	--	--
	25...	0720	20.0	96	--	--	--	--	--	--	--
	25...	0730	20.0	99	--	--	--	--	--	--	--
	25...	0740	20.0	100	--	--	--	--	--	--	--
	25...	0750	20.0	105	--	--	--	--	--	--	--
	25...	0805	20.0	108	--	--	--	--	--	--	--
	25...	0820	20.0	112	--	--	--	--	--	--	--
	25...	0840	20.0	110	--	--	--	--	--	--	--
	25...	0900	20.0	120	--	--	--	--	--	--	--
			03436139	- MOBLEY SPRING AT CLARKSVILLE, TN							
	FEB										
1	02...	1700	14.5	358	7.00	2.1	1.3	14	15	0.20	127
2	14-14	1515	--	684	--	--	--	--	--	--	--
--	29...	1030	15.0	500	7.80	2.5	1.3	19	18	0.20	217
	MAR										
4	25...	0520	17.0	460	--	--	--	--	--	--	--
	25...	0540	17.0	500	--	--	--	--	--	--	--
	25...	0600	17.0	550	--	--	--	--	--	--	--
	25...	0620	17.0	550	--	--	--	--	--	--	--
	25...	0640	17.0	560	--	--	--	--	--	--	--
	25...	0700	17.0	554	--	--	--	--	--	--	--
	25...	0730	17.0	549	--	--	--	--	--	--	--
	25...	0800	17.0	543	--	--	--	--	--	--	--
	25...	0840	17.0	563	--	--	--	--	--	--	--
	25...	0910	17.0	554	--	--	--	--	--	--	--

Table 3.--Selected trace-metal and oil-grease concentration data from storms 1-4 and from normal flow conditions

STORM	DATE	TIME	HARDNESS (MG/L AS CACO3) (00900)	CALCIUM TOTAL RECOV. (MG/L AS CA) (00915)	MAGNESIUM, TOTAL RECOV. (MG/L AS MG) (00925)	SODIUM, TOTAL RECOV. (MG/L AS NA) (00930)	SODIUM ADSORPTION RATIO (00931)	BARIUM, TOTAL RECOV. (UG/L AS BA) (01005)	BERYLLIUM, TOTAL RECOV. (UG/L AS BE) (01010)	CADMIUM TOTAL RECOV. (UG/L AS CD) (01025)	CHROMIUM, TOTAL RECOV. (UG/L AS CR) (01030)	COBALT, TOTAL RECOV. (UG/L AS CO) (01035)	COPPER, TOTAL RECOV. (UG/L AS CU) (01040)
					03436138 - HOSPITAL SINKHOLE AT CLARKSVILLE, TN								
1	FEB 02...	1630	27	9.8	0.68	2.5	0.2	20	<0.5	3	<5	<3	<10
2	FEB 14-14	1515	180	39	19	30	1	83	<0.5	<1	<5	<3	<10
3	FEB 19-19	0700	65	23	1.7	11	0.6	39	<0.5	2	10	<3	40
					03436139 - MOBLEY SPRING AT CLARKSVILLE, TN								
1	FEB 02...	1700	150	52	5.3	7.8	0.3	49	<0.5	2	<5	<3	<10
2	FEB 14-14	1515	210	47	23	28	0.9	11	<0.5	<1	<5	<3	<10
--	29...	1030	--	--	--	--	--	--	--	--	--	--	--

Table 3.--Selected trace-metal and oil-grease concentration data from storms 1-4 and from normal flow conditions (continued)

STORM	DATE	IRON, TOTAL RECOV. (UG/L AS FE) (01046)	LEAD, TOTAL RECOV. (UG/L AS PB) (01049)	MANGANESE, TOTAL RECOV. (UG/L AS MN) (01056)	MOLYBDENUM, TOTAL RECOV. (UG/L AS MO) (01060)	NICKEL, TOTAL RECOV. (UG/L AS NI) (01065)	SILVER, TOTAL RECOV. (UG/L AS AG) (01075)	STRONTIUM, TOTAL RECOV. (UG/L AS SR) (01080)	VANADIUM, TOTAL RECOV. (UG/L AS V) (01085)	ZINC, TOTAL RECOV. (UG/L AS ZN) (01090)	LITHIUM TOTAL RECOV. (UG/L AS LI) (01130)	OIL AND GREASE, TOTAL RECOV. GRAVIMETRIC (MG/L) (00556)
			03436138	- HOSPITAL SINKHOLE AT CLARKSVILLE, TN								
1	FEB 02...	820	<10	48	<10	<10	--	110	<6	130	33	<1
2	FEB 14-14	160	<10	95	10	<10	<1	220	<6	14	22	--
3	FEB 19-19	3000	50	89	<10	<10	--	140	7	150	<4	2
			03436139	- MOBLEY SPRING AT CLARKSVILLE, TN								
1	FEB 02...	2700	<10	99	<10	<10	--	200	<6	57	44	--
2	FEB 14-14	13	<10	4	10	<10	<1	350	28	65	12	--
--	29...	--	--	--	--	--	--	--	--	--	--	<1

during normal flow conditions, and all analyses of samples from the fourth storm have not been completed by the lab. Results from the GC/FID screening technique are presented as chromatograms (figs. 4-7) showing retention time versus magnitude of detector response (equivalent to concentration). Organic compounds in samples collected during the planned April-May sampling program will be determined using the gas chromatographic-mass spectrometric (GC/MS) analytical method (Wershaw and others, 1987). This method provides absolute identification and quantification of phenols, polynuclear aromatic hydrocarbons, and other base-neutral extractable organic compounds.

Drainage-Well Site (Hospital Sinkhole)

The samples of urban runoff at the drainage-well sites had specific-conductance values ranging from 65 to 650 uS/cm (microsiemens per centimeter). Concentrations of total-recoverable metals in the samples from storms 1 to 3 varied; of the 19 metals sampled, all but three (beryllium, cobalt, and nickel) were present in concentrations above the detection level. Concentrations of 11 metals were highest in the sample from storm 2; however, iron (as Fe) and lead (as Pb) were present in highest concentrations (3,000 and 50 ug/L, micrograms per liter, respectively) in samples from storm 3. Concentration of total recoverable oil and grease in the storm 1 sample was below the detection limit of 1 (milligrams per liter (mg/L), and in the storm 3 sample was 2 mg/L.

GC/FID screening of samples from the drainage-well site, storms 1 and 2 (figs. 4 and 5), indicate the presence of phenols, polynuclear aromatic hydrocarbons, and other base-neutral extractable organic compounds. Concentrations are low, ranging from 1 to 21 ug/L.

Mobley Spring Site

The samples collected from Mobley Spring during storms 1 and 2 had specific-conductance values of 358 and 684 uS/cm, respectively, compared to a value of 500 uS/cm in the sample collected during normal flow conditions. Total-recoverable concentrations of metals in the samples from storms 1 and 2 varied; of the 19 metals sampled, all but seven (beryllium, chromium, cobalt, copper, lead, nickel, and silver) were present in concentrations above the detection limit. Iron (as Fe) and manganese (as Mn) were present in high concentrations (2,700 and 99 ug/L, respectively) in samples from storm 1. The total-recoverable concentration of oil and grease was below the detection limit of 1 mg/L in the sample from normal flow conditions.

Organic compounds from all seven groups of methylene chloride-extractable organic compounds were present in the storm 1 sample. Concentrations could not be estimated because of interference by sample compounds with detection of internal standards and calculation of recovery rates. The concentrations for each compound reported in figure 6, ranging up to 730 ug/L, may therefore be lower than the actual values.

The sample from normal flow conditions contained phenols, polynuclear aromatic hydrocarbons, and other base-neutral extractable organic compounds

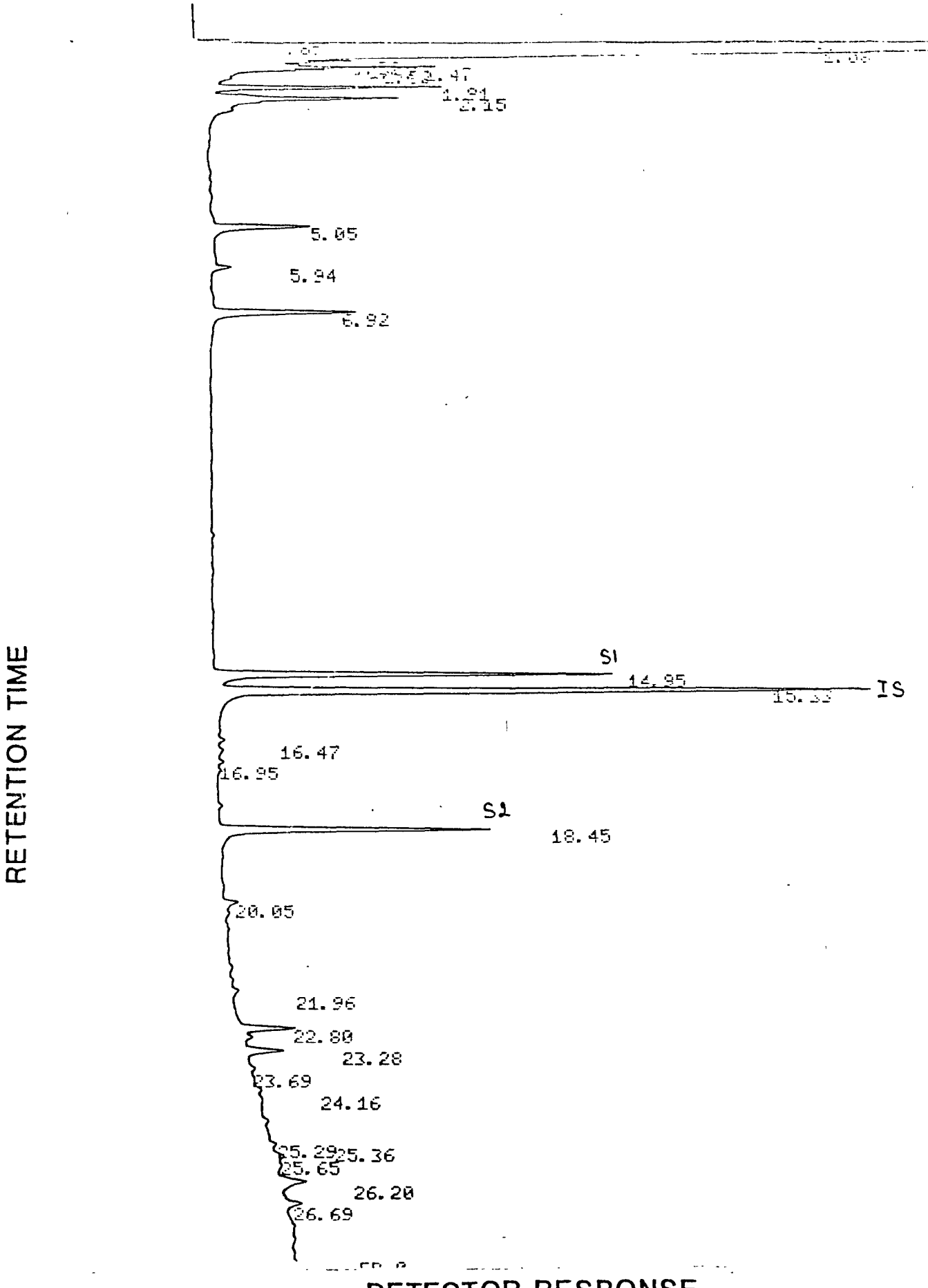

Figure 4.--Chromatogram and estimates of concentration of organic compound

NAME	UG/L	RT	AREA	BC	RF	RRT
9	12.851	5.05	286798	01	1.471	0.329
10	1.984	5.94	44266	01	1.471	0.387
11	20.968	6.92	467954	01	1.471	0.451
2,2-DFB.	53.101	14.95	1261759	01	1.381	0.975
1,1-BIPHEN INTERNAL STD		15.33	1969322	01		1.
2,4,6-TBP.	144.9	18.45	866834	01	5.487	1.204
15	2.153	20.05	48057	01	1.471	1.388
16	7.524	22.8	167898	01	1.471	1.487
17	6.096	23.28	136054	01	1.471	1.519
18	4.746	24.16	105915	02	1.471	1.576
19	4.051	25.29	90405	02	1.471	1.65
20	2.308	25.36	51518	02	1.471	1.654
21	6.041	25.65	134816	02	1.471	1.673
22	7.402	26.2	165197	02	1.471	1.709
23	3.284	26.69	73271	03	1.471	1.741
TOTALS	277.409		5870064			

SUMMARY REPORT INDEX 1 FILE 1. CH= "B" PS= 1.

NAME	UG/L
4-PICOLINE	0.
2-MP.	0.
2,4-DMP.	0.
3,5-DMP.	0.
NAPHTHALEN	0.
QUINOLINE	0.
2,2-DFB.	53.101
1,1-BIPHEN	0.
DIBENZOFUR	0.
2,4,6-TBP.	144.9
UNKNOWNS	79.408
TOTAL	277.409

Figure 4.--Chromatogram and estimates of concentration of organic compounds for the sample from the drainage-well site for storm 1, February 2, 1988 (continued).

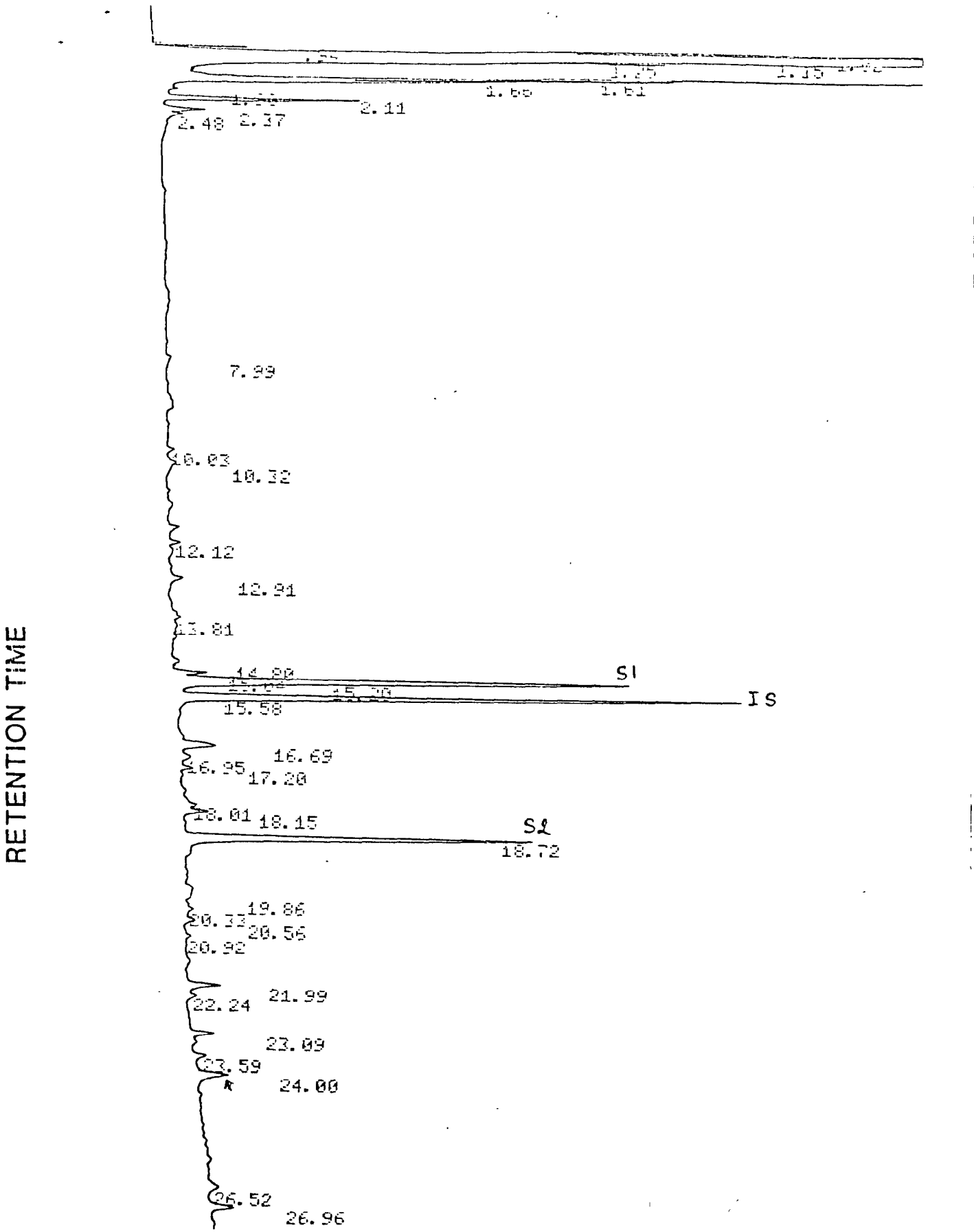

Figure 5.--Chromatogram and estimates of concentrations of organic compounds for the sample from the drainage-well site for storm 2, February 14, 1988.

NAME	UG/L	RT	AREA	BC	RF	RRT
10	7.24	15.04	85084	02	1.938	0.965
2,2-DFB.	98.346	15.2	1631425	02	1.373	0.976
1,1-BIPHEN	INTERNAL STD	15.58	1710307	03		1.
DIBENZOFUR	10.209	16.69	146286	01	1.59	1.071
14	6.308	18.15	74131	03	1.938	1.165
2,4,6-TBP.	281.094	18.72	1177604	01	5.437	1.202
16	6.723	19.86	79003	02	1.938	1.275
17	3.188	20.56	37468	03	1.938	1.32
18	10.694	21.99	125680	03	1.938	1.411
19	5.777	23.09	67894	01	1.938	1.482
20	3.732	23.59	43853	01	1.938	1.514
21	10.832	24.	127311	01	1.938	1.54
22	4.9	26.52	57586	01	1.938	1.702
23	7.506	26.96	88208	01	1.938	1.73
TOTALS	456.549		5451845			

SUMMARY REPORT INDEX 1 FILE 1. CH= "A" PS= 1.

NAME	UG/L
4-PICOLINE	0.
2-MP.	0.
2,4-DMP.	0.
2,5-DMP.	0.
NAPHTHALEN	0.
QUINOLINE	0.
2,2-DFB.	98.346
1,1-BIPHEN	0.
DIBENZOFUR	10.21
2,4,6-TBP.	281.094
UNKNOWNS	66.899
TOTAL	456.549

Figure 5.--Chromatogram and estimates of concentrations of organic compounds for the sample from the drainage-well site for storm 2, February 14, 1988. (continued).

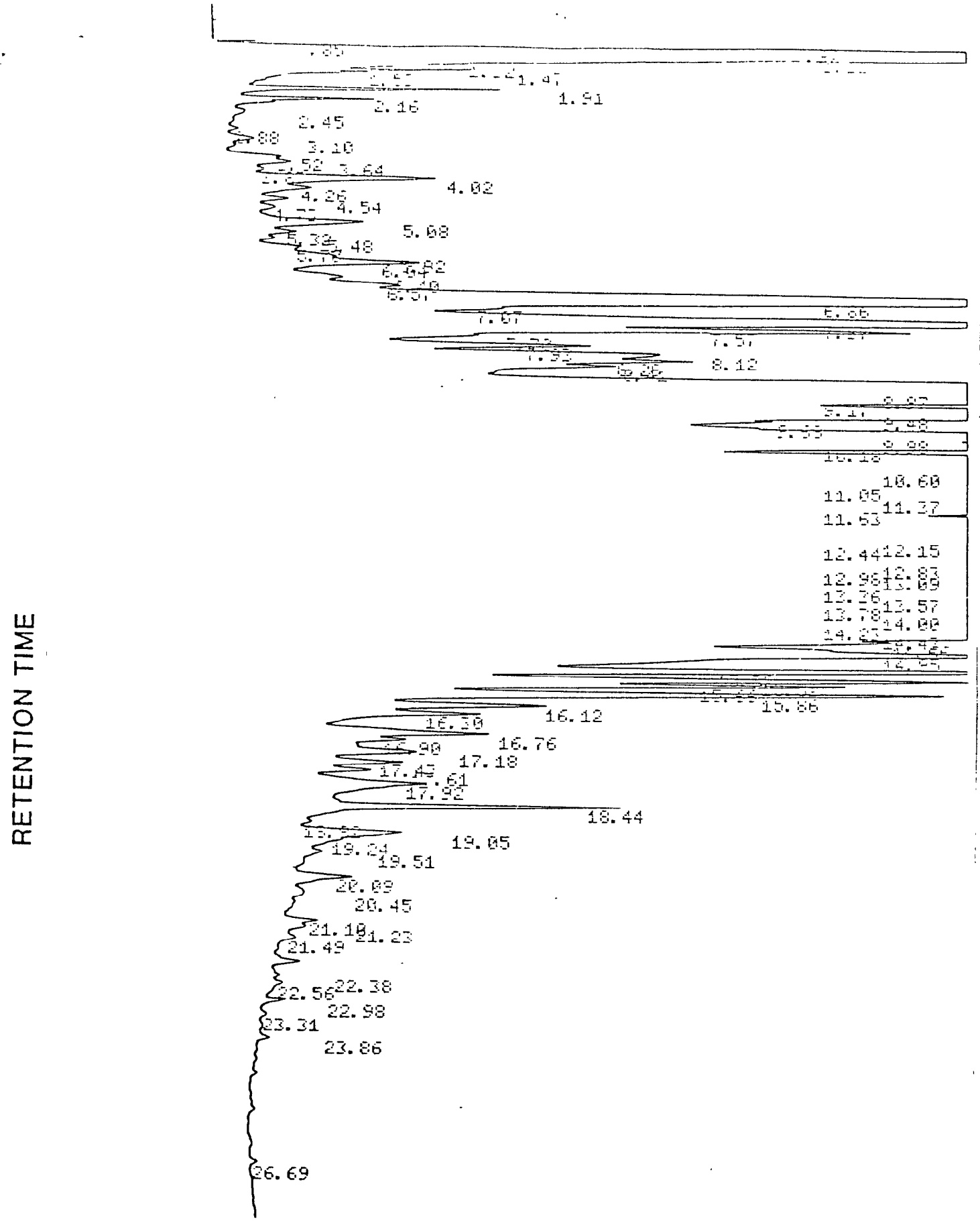

Figure 6.--Chromatogram and estimates of concentrations of organic compound for the sample from Mobley Spring for storm 1, February 2, 1988.

NAME	UG/L	RT	AREA	BC	FF	TF
17	11.491	5.08	1024272	02	1.471	0.34
18	3.574	5.32	318556	02	1.471	0.356
19	2.197	5.48	195829	02	1.471	0.367
20	4.545	5.7	405045	02	1.471	0.381
21	6.224	5.92	554822	02	1.471	0.396
22	13.971	6.04	1245205	02	1.471	0.404
4-PICOLINE	8.191	6.4	730102	02	1.471	0.428
24	10.052	6.57	895956	02	1.471	0.439
25	729.921	6.86	65059597	09	1.471	0.459
26	137.065	7.37	12216881	06	1.471	0.493
27	24.094	7.57	2147547	06	1.471	0.506
28	2.317	7.7	206378	05	1.471	0.515
29	8.68	7.93	773657	06	1.471	0.53
30	17.908	8.12	1596129	06	1.471	0.543
31	13.658	8.28	1217354	06	1.471	0.554
32	15.702	8.41	1399632	06	1.471	0.563
33	267.427	8.97	23749581	06	1.471	0.6
34	136.291	9.17	12147924	06	1.471	0.613
35	252.37	9.48	22503448	06	1.471	0.634
36	13.746	9.68	1225241	06	1.471	0.647
37	190.794	9.98	17005928	06	1.471	0.668
2-MP.	63.834	10.18	10205692	06	0.82	0.681
39	456.097	10.6	40118223	06	1.471	0.709
40	359.	11.05	31938462	06	1.471	0.739
41	139.253	11.37	12411938	06	1.471	0.761
2,4-DMP.	133.268	11.62	22034706	06	0.793	0.778
2,5-DMP.	595.833	12.15	54384712	06	1.436	0.813
NAPHTHALEN	30.474	12.44	4295016	06	0.93	0.832
45	364.711	12.83	32507515	06	1.471	0.858
46	64.242	12.98	5726078	06	1.471	0.868
QUINOLINE	13.492	13.09	1609531	06	1.099	0.876
48	185.319	13.36	16517891	06	1.471	0.894
49	120.125	13.57	10707048	06	1.471	0.908
50	143.787	13.78	12816117	06	1.471	0.922
51	97.403	14.	8681757	05	1.471	0.936
52	185.531	14.23	16536760	06	1.471	0.952
53	140.728	14.43	12543463	06	1.471	0.965
2,2-DFB.	22.517	14.66	2136869	06	1.381	0.981
1,1-BIPHEN INTERNAL STD		14.95	8017594	06		1.
56	42.438	15.32	3782544	06	1.471	1.025
57	30.088	15.52	2681874	06	1.471	1.038
58	22.187	15.66	1977573	06	1.471	1.047
59	32.68	15.86	2912791	06	1.471	1.061
60	11.639	16.12	1037389	06	1.471	1.078
61	9.321	16.3	830803	06	1.471	1.09
DIBENZOFUR	11.002	16.76	896888	06	1.608	1.121
63	4.277	16.9	390172	05	1.471	1.13
64	7.951	17.18	709639	06	1.471	1.149
65	4.935	17.42	439899	06	1.471	1.166
66	2.819	17.61	251253	06	1.471	1.178
2,4,6-TBP.	46.627	17.92	1114042	06	5.487	1.199
68	16.877	18.44	1511179	06	1.471	1.233
70	7.246	19.05	654819	06	1.471	1.274
71	2.879	19.24	256613	06	1.471	1.287
72	3.152	19.51	280915	05	1.471	1.305
73	4.415	20.09	1953?4	06	1.471	1.344
74	2.941	20.45	262108	06	1.471	1.368
75	1.8	21.1	160486	06	1.471	1.411
76	1.509	21.21	137134	06	1.471	1.42
77	1.489	21.49	132747	07	1.471	1.437
78	1.147	22.56	102196	02	1.471	1.509
79	1.014	22.98	90437	03	1.471	1.537
TOTPLS	5352.575		500044022			

SUMMARY REPORT INDEX 1 FILE 1. CH= "B" PS= 1.

NAME	UG/L
4-PICOLINE	8.191
2-MP.	63.834
2,4-DMP.	133.269
2,5-DMP.	595.833
NAPHTHALEN	30.473
QUINOLINE	13.492
2,2-DFB.	22.517
1,1-BIPHEN	0.
DIBENZOFUR	11.002
2,4,6-TBP.	46.627
UNKNOWNS	4427.337
TOTAL	5352.575

Figure 6.--Chromatogram and estimates of concentrations of organic compounds for the sample from Mobley Spring for storm 1, February 2, 1988 (continued).

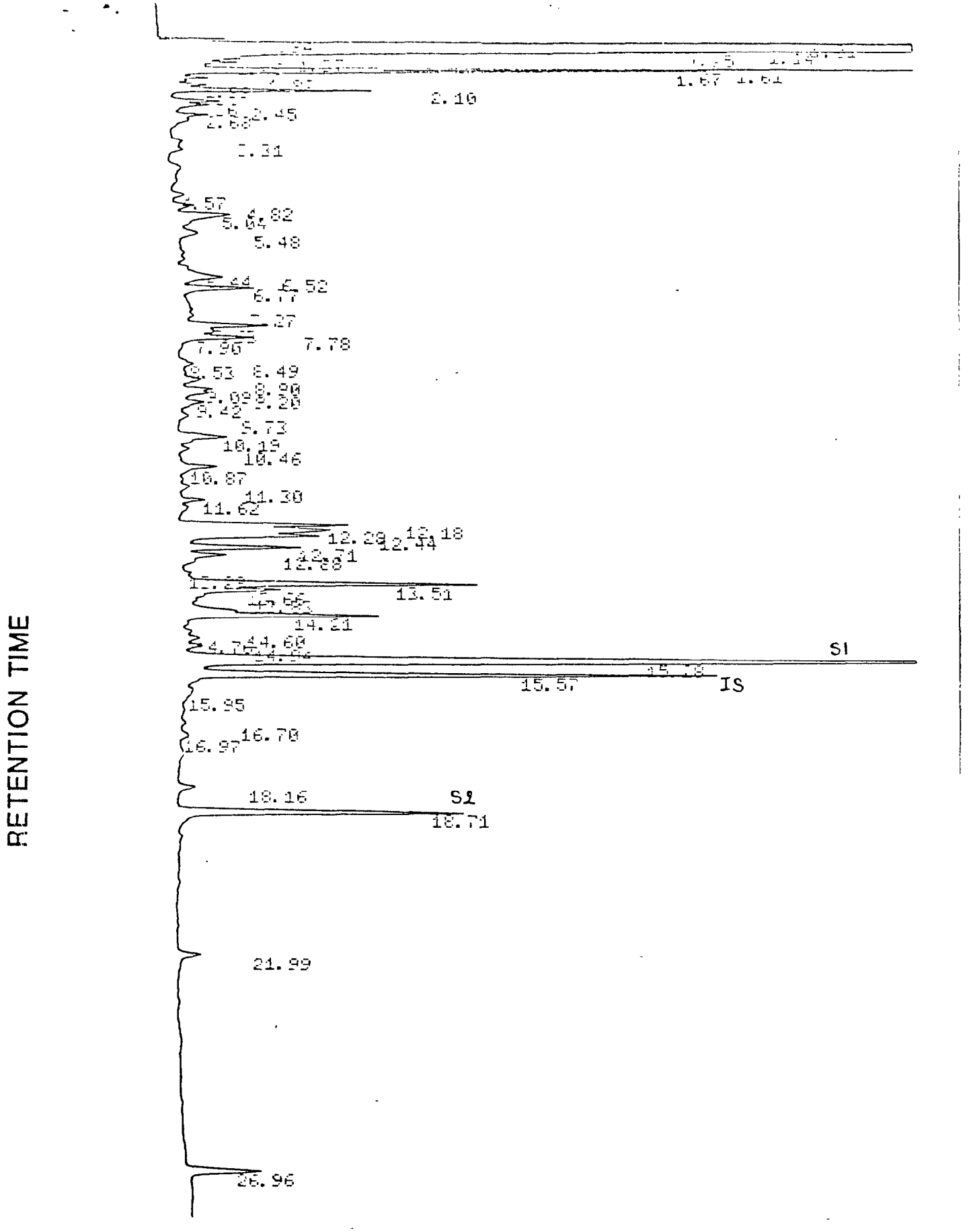

Figure 7.--Chromatogram and estimates of concentrations of organic compounds for the sample from Mobley Spring for normal flow conditions, February 29, 1988.

NAME	UG/L	RT	AREA BC	RF	RRT
15	10.444	5.04	351000 02	1.938	0.33
16	3.821	5.48	128399 03	1.938	0.359
17	2.451	6.44	82385 02	1.938	0.421
18	5.516	6.52	185367 03	1.938	0.427
4-PICOLINE	6.791	6.77	228234 01	1.938	0.443
20	8.859	7.63	297717 02	1.938	0.499
21	2.482	7.78	83426 02	1.938	0.509
22	7.862	7.9	264196 03	1.938	0.517
23	1.91	8.9	64191 02	1.938	0.582
24	2.501	9.09	84067 02	1.938	0.595
25	2.686	9.2	90256 02	1.938	0.602
26	2.721	9.42	91442 03	1.939	0.616
27	1.073	9.73	36082 01	1.938	0.637
28	4.424	10.19	148677 01	1.938	0.667
2-MP.	1.647	10.87	136481 01	0.786	0.711
31	12.288	12.18	446578 02	1.938	0.797
3,5-DMP.	15.552	12.28	740565 02	1.368	0.804
33	12.811	12.44	430564 03	1.938	0.814
NAPHTHALEN	4.31	12.71	291284 02	0.964	0.832
35	2.797	12.88	94020 03	1.938	0.843
QUINOLINE	19.803	13.51	887726 02	1.453	0.884
37	9.571	13.66	321648 03	1.938	0.894
38	21.735	14.21	730463 01	1.938	0.93
39	1.732	14.76	58206 02	1.938	0.966
2,2-DFB.	1.272	14.94	60356 02	1.373	0.978
1,1-BIPHEN INTERNAL STD		15.28	4053700 02		1.
42	50.123	15.57	1684464 03	1.938	1.019
43	1.122	15.95	37721 01	1.938	1.044
2,4,6-TBP.	5.482	18.16	65680 01	5.437	1.188
46	28.421	18.71	955132 01	1.938	1.224
47	2.39	21.99	80332 01	1.938	1.439
49	8.875	26.96	298256 01	1.938	1.764
TOTALS	266.094		13605688		

SUMMARY REPORT INDEX 1 FILE 1. CH= "A" PS= 1.

NAME	UG/L
4-PICOLINE	6.791
2-MP.	1.647
2,4-DMP.	0.687
3,5-DMP.	15.551
NAPHTHALEN	4.31
QUINOLINE	19.802
2,2-DFB.	1.273
1,1-BIPHEN	0.
DIBENZOFUR	0.935
2,4,6-TBP.	5.482
UNKNOWNS	209.616

Figure 7.--Chromatogram and estimates of concentrations of organic compounds for the sample from Mobley Spring for normal flow conditions, February 29, 1988 (continued).

(fig. 7). Although reported concentrations are probably low for this analysis as well, because of interference with recovery of the internal standard, they appear to be lower (less than 51 ug/L) than the levels in the storm 1 sample.

Comparison with Drinking-Water Standards

Analyses of the samples are compared with the State primary and secondary drinking-water standards (Tennessee Division of Water Management, 1977). Comparison of levels for trace-metal data is not straightforward because samples were analyzed for total levels (dissolved and suspended), whereas drinking-water standards apply to the dissolved phase only. The primary maximum contaminant level of 50 ug/L for lead (as Pb) was exceeded by the drainage-well site sample from storm 1. The secondary maximum contaminant level of 300 ug/L for iron (as Fe) was exceeded by drainage-well site and spring samples, and the secondary maximum contaminant level of 50 ug/L for manganese (as Mn) was equaled by one drainage-well site sample.

SUMMARY

A drainage-well and a spring site in Clarksville, Tennessee, have been instrumented to collect storm-related data in order to define the water quality of stormwater runoff and receiving ground water. A dye-trace test verified the direct connection between surface drainage at the drainage well at Clarksville Memorial Hospital with the ground-water system flowing to Mobley Spring. Automated water-quality samplers collect discrete samples at selected time intervals throughout a storm event, and stage is recorded at each site. Samples of storm runoff and spring flow were collected during four storms and during normal flow conditions during February and March 1988.

Samples were analyzed selectively for major water-quality constituents, selected trace metals, and organic compounds. Several samples from the drainage well and the spring had trace-metal concentrations that exceeded maximum contaminant levels for State drinking-water standards. Phenols, polynuclear aromatic hydrocarbons, and other base-neutral extractable organic compounds were present in samples from both the drainage well and spring. The highest concentrations of these compounds occurred in samples collected at Mobley Spring during a storm event.

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* METHYLENE CHLORIDE EXTRACTABLE COMPOUNDS *

* (Priority Pollutant Organic Compounds and other Hazardous Organic *

* Substances; Prepared from Supelpreme-HC Standards from SUPELCO, Inc.) *

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[RRT - retention time on gas chromatigraphic column relative to internal standard]

Group: 1 PHENOLS

RRT	Compound Names	Detection Limit Range (ug/L)
0.59	2-Chlorophenol	1-5
0.58	Phenol	1-5
0.75	2-Nitrophenol	5-10
0.77	2,4-Dimethylphenol	1-5
0.79	2,4-Dichlorophenol	5-10
0.91	4-Chloro-3-methylphenol	5-10
0.97	2,4,6-Trichlorophenol	5-10
1.11	2,4-Dinitrophenol	10-20
1.13	4-Nitrophenol	10-20
1.19	2-Methyl-4,6-dinitrophenol	5-10
1.31	Pentachlorophenol	10-20

Group: 2 BASE-NEUTRAL # 1

RRT	Compound Names	Detection Limit Range (ug/L)
0.23	N-Nitrosodimethylamine	1-5
0.58	Bis (2-Chloroethyl) Ether	1-5
0.66	Bis (2-Chloroisopropyl) Ether	1-5
0.68	N-Nitrosodi-n-Propylamine	1-5
0.78	Bis (2-Chloroethoxy) Methane	1-5
1.06	Dimethyl Phthalate	1-5
1.18	Diethyl Phthalate (Coeluted)	1-5
1.18	4-Chlorophenylphenyl Ether (Coeluted)	
1.20	N-Nitrosodiphenylamine	1-5
1.26	4-Bromophenylphenyl Ether	1-5
1.44	Di-n-Butyl Phthalate	1-5
1.68	Butyl Benzyl Phthalate	1-5
1.79	Bis (2-Ethylhexyl) Phthalate	1-5
1.88	Di-n-Octyl Phthalate	1-5

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METHYLENE CHLORIDE EXTRACTABLE COMPOUNDS
(Priority Pollutant Organic Compounds and other Hazardous Organic Substances; Prepared from Supelpreme-HC Standards from SUPELCO, Inc.)

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[RRT = retention time on gas chromatigraphic column relative to internal standard]

Group: 3 BASE-NEUTRAL # 2

RRT	Compound Names	Detection Limit Range (ug/L)
0.61	1,4-Dichlorobenzene	1-5
0.62	1,3-Dichlorobenzene	1-5
0.64	1,2-Dichlorobenzene	1-5
0.69	Hexachloroethane	10-20
0.70	Nitrobenzene	1-5
0.74	Isophorone	1-5
0.80	1,2,4-Trichlorobenzene	1-5
0.84	Hexachlorobutadiene	10-20
0.96	Hexachlorocyclopentadiene	10-20
1.00	2-Chloronaphthalene(Coeluted w IS)	1-5
1.07	2,6-Dinitrotoluene	1-5
1.13	2,4-Dinitrotoluene	1-5
1.21	Azobenzene	1-5
1.28	Hexachlorobenzene	5-10

Group: 4 HAZARDOUS SUBSTANCES # 1

RRT	Compound Names	Detection Limit Range (ug/L)
0.67	2-Methylphenol	5-10
0.69	4-Methylphenol	5-10
0.79	Benzoic acid	10-20
0.98	2,4,6-Trichlorophenol	5-10

Group: 5 HAZARDOUS SUBSTANCES # 2

RRT	Compound Names	Detection Limit Range (ug/L)
0.57	Aniline	5-10
0.64	Benzyl Alcohol	5-10
0.83	3-Nitroaniline	5-10
0.92	4-Chloroaniline	1-5
1.02	2-Methylnaphthalene	5-10
1.09	2-Nitroaniline	5-10
1.12	Dibenzofuran	1-5
1.19	4-Nitroaniline	5-10

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METHYLENE CHLORIDE EXTRACTABLE COMPOUNDS
(Priority Pollutant Organic Compounds and other Hazardous Organic Substances; Prepared from Supelpreme-HC Standards from SUPELCO, Inc.)

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[RRT - retention time on gas chromatigraphic column relative to internal standard]

Group: 6 POLYNUCLEAR AROMATIC HYDROCARBONS (PAH)

RRT	Compound Names	Detection limit Range (ug/L)
0.81	Naphthalene	1-5
1.06	Acenaphthylene	1-5
1.09	Acenaphthene	1-5
1.18	Fluorene	1-5
1.33	Phenanthrene (Coeluted)	1-5
1.33	Anthracene (Coeluted)	1-5
1.52	Fluoranthene	1-5
1.55	Pyrene	1-5
1.75	Benzo(a) Anthracene (Coeluted)	1-5
1.75	Chrysene (Coeluted)	1-5
1.92	Benzo(b) Fluoranthene (Coeluted)	1-5
1.92	Benzo(k) Fluoranthene (Coeluted)	1-5
1.96	Benzo(a) Pyrene	1-5
2.15	Dibenzo(a,h) Anthracene (Coeluted)	5-10
2.15	Indeno(1,2,3-cd) Pyrene (Coeluted)	5-10
2.19	Benzo(g,h,i) Perylene	5-10

Group: 7 PESTICIDES

RRT	Compound Names	Detection Limit Range (ug/L)
1.26	α-BHC	5-10
1.30	β-BHC	5-10
1.31	γ-BHC	5-10
1.34	δ-BHC	5-10
1.41	Heptachlor	5-10
1.46	Aldrin	5-10
1.51	Heptachlor Epoxide	5-10
1.56	Endosufan I	5-10
1.59	Dieldrin (Coeluted)	5-10
1.59	4,4-DDE (Coeluted)	5-10
1.62	Endrin	5-10
1.63	Endosufan II	5-10
1.64	4,4-DDD	5-10
1.65	Endrin Aldehyde	5-10
1.69	Endosufan Sulfate (Coeluted)	5-10
1.69	4,4-DDT (Coeluted)	5-10